Municipal sewage sludge and fish waste based composite adsorbents for removal of organic contaminants from water

Rui Ding[1], Rajiv Wallace[2], Mycola Seredych[2], Teresa J. Bandosz[2], and Pengfei Zhang[1]
[1]Dept. of Earth & Atmospheric Sciences, [2]Dept. Of Chemistry, City College of New York, CUNY

Abstract

Municipal sewage sludge from a wastewater treatment plant and fish waste from a seafood market were mixed at different weight ratios, dried at 120 ºC, and pyrolyzed at 950 ºC in a nitrogen atmosphere to obtain composite adsorbents. Batch adsorption experiments were then conducted to examine the adsorption of volatile organic compounds (VOCs), nitrosamines, and pharmaceuticals/endocrine disrupting compounds (EDCs) by the composite materials and a commercially available activated carbon. A synergistic effect was observed when the sewage sludge and fish waste were combined. The maximum amounts of VOCs, nitrosamines, and pharmaceuticals/EDCs adsorbed by the composite materials are 4.9-7.2 mg/g, 10-16 mg/g, and 20-23 mg/g, respectively. The adsorption capacities of the composition materials for the aforementioned compounds are roughly 1/2 to 1/3 of those of the activated carbon, even though the surface areas and pore volumes of the composite materials are less than 1/10 of those of the activated carbon. The conversion of sewage sludge and fish wastes to adsorbents would eliminate the contamination of water resources by these wastes. These waste derived adsorbents may be used in water treatment processes for the removal of a large number of organic contaminants.

Introduction

Municipal sewage sludge, often referred to as biosolids, is a mixture of exhausted biomass generated in the aerobic and anaerobic digestion of the organic constituents of municipal sewage along with inorganic materials such as sand and metal oxides. Other sludges include wastes from industries such as shipyards, foundry, tobacco, electroplating, paper mills, etc. It is estimated that the United States produces about 10 million dry tons of sewage sludge annually [1].

Various methods have been used to dispose of or utilize municipal sewage sludge, including incineration, landfilling, road surfacing, conversion to fertilizer, compression into building blocks, and carbonization [1]. Since 1976 several patents (e.g., Bandosz and Bagreev [2]) have been issued on carbonization of sewage sludge and various applications of the final materials. Carbonization of sludge in the presence of chemical activating agents such as zinc chloride and sulfuric acid produces new adsorbents, with patented applications in processes such as removal of organics in the final stages of water cleaning. Industrial sludges after dewatering processes/drying are usually disposed of as hazardous wastes.

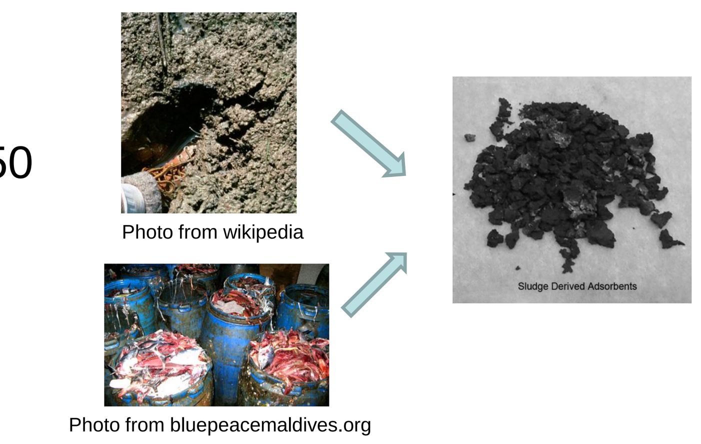
Fish waste, like sewage sludge, is another type of waste that is generated in large quantities (e.g., over 70 million tons/yr globally [3]) and needs to be properly treated or disposed of. Fish waste is a source of carbonaceous materials and contains phosphorus, calcium, and magnesium that could form catalytic centers after pyrolysis. Fatty acids contained in fish waste could be converted to bio-fuel during pyrolysis if so desired.

The overall goal of the project is to establish a new technological process for the production of catalytically active composite materials based on municipal sewage sludge, for the removal of a wide range of organic contaminants from drinking water sources and systems.

Methods

Adsorbents

- Raw materials:
  - Dewatered sewage sludge (SS) from Wards Island Water Pollution Control Plant , NYC, NY
  - Fish waste (F) from a seafood market in NJ
  - or their mixtures (SSF, 90:10, 75:25, and 50:50 ratio based on wet mass)
- Dried at 120 ºC
- Pyrolyzed at 950 ºC in a nitrogen atmosphere in a fixed bed (horizontal furnace)
- 5 different adsorbents:
  - SS
  - SS90F10, SS75F25, SS50F50
  - F
- A wood-based activated carbon (WVA900)



Organic pollutants:

- Volatile organic compounds: benzene, carbon tetrachloride, 1,2-dichloroethane, 1,2-dichloropropane, dichloromethane, tetrachloroethylene, trichloroethylene, vinyl chloride, aniline, benzyl chloride, 1,3-butadiene, 1,1-dichloroethane, nitrobenzene, oxirane methyl, and 1,2,3-trichloropropane
- Nitrosamines: N-nitroso-diethylamine (NDEA), N-nitroso-dimethylamine (NDMA), N-nitroso-di-n-butylamine (NDBA), N-nitroso-di-n-propylamine (NDPA), N-nitroso-methylethylamine (NMEA), and N-nitroso-pyrrolidine (NPYR)
- Pharmaceuticals and EDCs:atenolol, atrazine, carbamazepine, gemfibrozil, naproxen, phenytoin, sulfamethoxazole, and trimethoprim

Experimental procedures:

- Batch adsorption experiments to determine adsorption isotherms and maximum amount adsorbed
- Headspace GC/MS for analysis of VOCs
- LC/MS/MS for analysis of nitrosamines and pharmaceuticals/EDCs

Acknowledgments

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2. Bandosz, T. J.; Bagreev, A. Preparation of adsorbents from organic fertilizer and mineral oil and their application for removal of acidic gases from sulfur containing wet gas streams. Patent 6,962,616, 2005.
3. FAO The state of world fisheries and aquaculture; Food and Agriculture Organization: Rome, 2006.

Results

Adsorption of VOCs

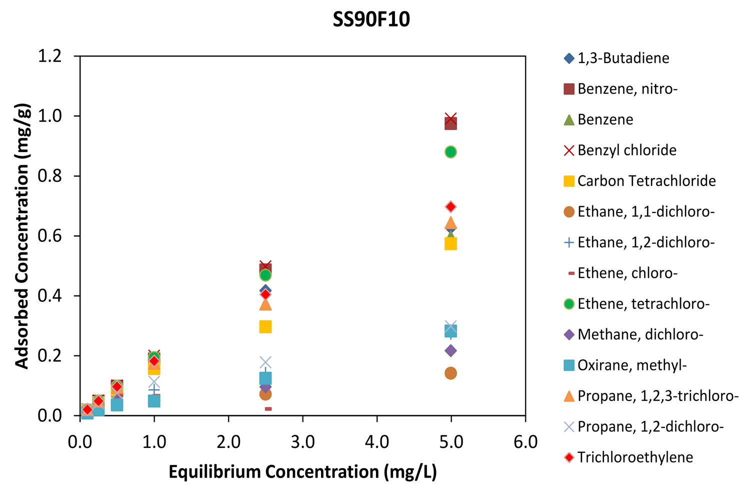

Fig. 1. Example of adsorption isotherms.

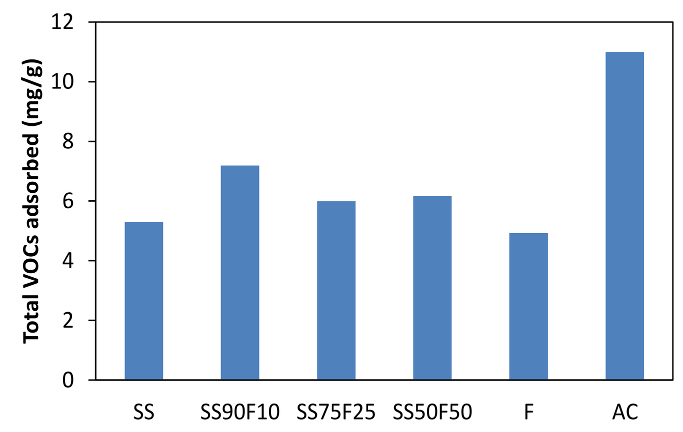

Figure 2. Total amount adsorbed.

Adsorption of Nitrosamines

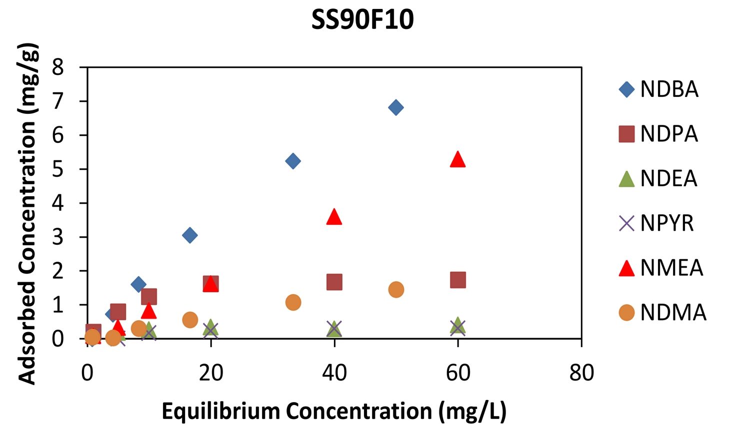

Fig. 3. Example of adsorption isotherms.

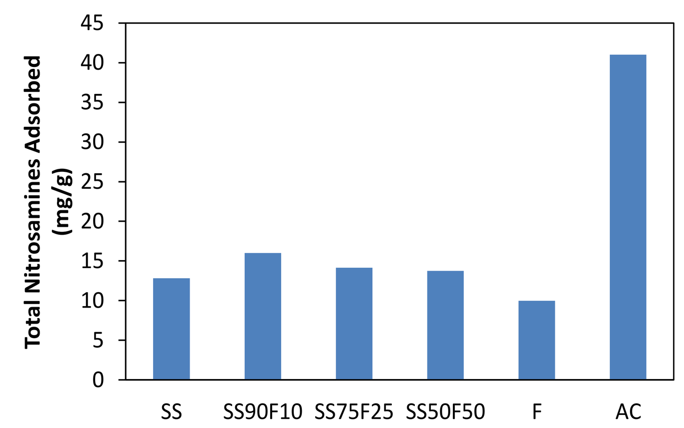

Figure 4. Total amount adsorbed.

Adsorption of pharmaceuticals and EDCs

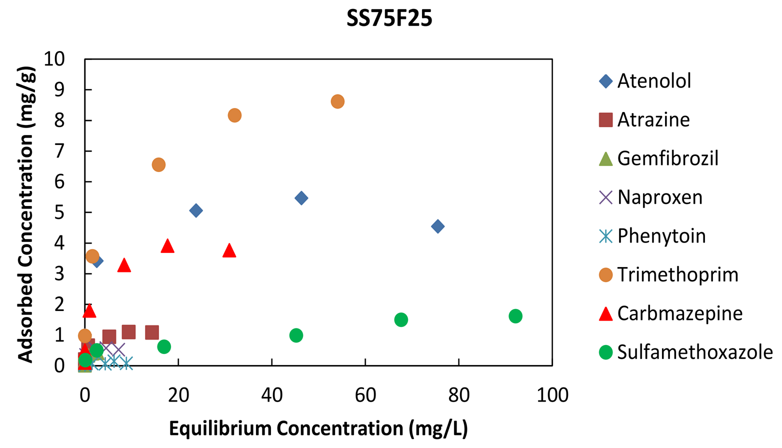

Fig. 5. Example of adsorption isotherms.

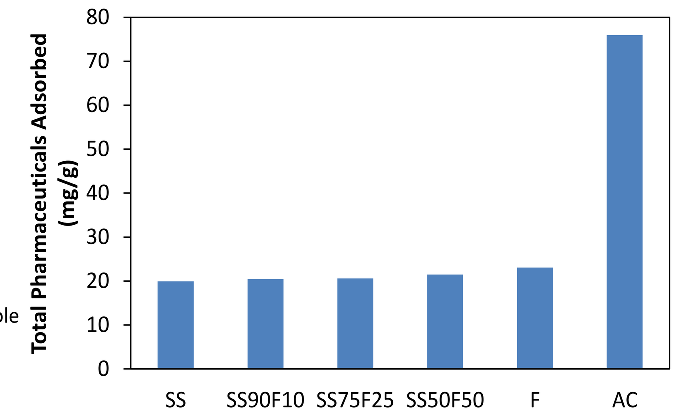

Figure 6. Total amount adsorbed.

Table 1. Amount of individual pharmaceuticals and EDCs adsorbed (mg/g).

	Atenolol	Atrazine	Gemfibrozil	Naproxen	Phenytoin	Trimetho-prim	Carbmaze-pine	Sulfamethoxa-zole	SUM
SS	7.8	0.9	0.2	0.0	0.0	8.1	2.9	0.0	19.9
SS90F10	7.8	1.1	0.2	0.0	0.0	8.3	3.1	0.0	20.5
SS75F25	4.5	1.1	0.4	0.5	0.1	8.6	3.8	1.6	20.6
SS50F50	4.6	1.2	0.6	0.8	0.0	8.6	4.2	1.4	21.5
F	6.8	0.8	0.4	0.8	0.2	9.0	3.4	1.7	23.0

Summary

- For VOCs, SS90F10, SS75F25 and SS50F50 materials performed better than the SS or F material, suggesting some synergistic effects; maximum adsorbed amounts about ½ of the amount by AC
- For nitrosamines, SS90F10, SS75F25, and SS50F50 also performed better than the SS or F materials; maximum adsorbed amounts ~ 1/3 of the amount by AC
- For pharmaceuticals and EDCs, total maximum amounts adsorbed by the five materials were similar but adding fish waste increased the number of species adsorbed; maximum adsorbed amounts about 1/3 of those by AC